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A review on existing and future energy sources for electrical power generation in Malaysia

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ABSTRACT

As the electricity demand is affected by population growth, Malaysia towards an industrialized nation is considering the options for future energy sources for its power generation. Besides the conventional four-fuel mix, the five-fuel mix strategy under several national policies are introduced to diversify and expanding the resources to incorporate renewable energy and nuclear. In view of Malaysia will become a net energy importer by 2020, the increase in alternative energy shares at least will provide stable energy security, more economical and greener environment. In this paper, present and future energy sources are discussed to emphasis on the constraints and barriers facing Malaysia towards energy security and sustainability. Several preferences on future energy sources are under serious consideration where renewable energy (RE) is becoming one of the popular choices as Malaysia recognizes the potential of RE as sustainable and greener option.

Contents

1. Introduction

Electricity is accepted as one of the driving forces of economic development of all the nations. The challenge of continuously generating electricity and meeting the growing demands exerting tremendous pressure on the energy infrastructures for both developed and developing countries [1].

As a developing country, Malaysia population of 27.4 million in 2007 with an average annual growth rate of 1.8% will reach to 33.4 million by the year 2020 and approximately 37.4 million in 2030 [2,3]. In 2009, the total electrical energy generated was 103.2 TWh [4] and the demand is expected to increase by 4.7% per annum

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Table 1
Fuel mix in electricity generation, 2000–2010.

Year	% of total					Total (GWh)
	Oil	Coal	Gas	Hydro	Others	
2000	4.2	8.8	77.0	10.0	0.0	69,280
2005	2.2	21.8	70.2	5.5	0.3	94,299
2010	0.2	36.5	55.9	5.6	1.8	137,909

to 274 TWh by the year 2030. It will heavily influenced by strong demands from the industrial and residential sectors as Malaysia enters into an industrialized nation, whereby per capita electricity demand is expected to reach 7571 kWh/person in the year 2030, more than double from 2002 [5].

Malaysia existing electricity generation mainly divided into 5 types of sources; oil, coal, natural gas, hydro and others (biomass, biogas and solar). In subsequent years natural gas expected to be gradually replaced by coal in the electricity generation mix. Efforts were undertaken to reduce the high reliance on natural gas in the generation mix by increasing the use of coal. As a result, the share of coal to the total generation mix increased from 8.8% in 2000 to 21.8% in 2005 while that of natural gas decreased from 77.0% to 70.2%, as shown in Table 1 [6]. Consequently, the share of natural gas in the electricity generation fuel mix will be reduced from 74% in 2002 to 45% in 2030, while the share of coal will increase to 50% in 2030 [5].

Malaysia National Energy Policy had introduced 3 principal energy objectives that are instrumental in guiding the future energy sector development. They are: (1) the supply objective – to ensure the provision of adequate, secure, and cost-effective energy supplies through developing indigenous energy resources both non-renewable and renewable energy resources using the least cost options and diversification of supply sources both from within and outside the country; (2) the utilization objective – to promote the efficient utilization of energy and to discourage wasteful and non-productive patterns of energy consumption; and (3) the environmental objective – to minimize the negative impacts of energy production, transportation, conversion, utilization and consumption on the environment [7].

The National Depletion Policy was formulated to prolong and preserve the economy's energy resources, particularly oil and gas resources. To diversify the fuel mix used in electricity generation, the economy introduced in 1981 the Four-Fuel Diversification Strategy. The initial focus of this policy was to reduce the economy's overdependence on oil as the principal energy source, and it aimed for an optimal fuel mix of oil, gas, hydro and coal for use in electricity generation. As a result, oil's domination of the generation fuel mix has been significantly reduced and replaced with gas and coal. In 2002, the Five-Fuel Diversification Strategy was expanded to incorporate renewable energy as the fifth fuel after oil, gas, coal and hydro. Nuclear energy is presently not in used, but the provision to consider nuclear potential as one option for future power generation is in progress [2,8].

2. Past and present energy for power generation

Malaysia's electrical power generation is mainly dominated by 3 major power producers; Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd. (SESB) and Sarawak Electricity Supply Corp. (SESCO). Until end of 2010, the total plants generating capacity is estimated at 26,265 MW where the fuel mix for generation constitutes of 57% natural gas, 24.1% coal, 8.4% hydro, 6.4% oil/diesel and 4.2% biomass/others. Fig. 1 shows the fuel mix trend in power generation from Malaysia Energy Commission forecast [9]. It indicates the oil & distillate portion of the fuel mix has drastically reduced from as high as 90% oil dependence in 1978 to less than 7% in 2010. To balance the mix ratio, as Malaysia has abundant reserves of natural gas, the trend of natural gas introduced into the generation has increased from a merely less than 5% in 1978 to significant portion of 57% in 2010.

Currently, generation reserve margin of Peninsula Malaysia stands at 40% and the Economic Planning Unit of Malaysia estimates reserve margins for Peninsular Malaysia will be adequate at 25.4%. Projections for Sabah and Sarawak to be at 37.2% and 24.5% respectively and the generation reserve margins to achieve at a prudent level by 2016 [10].

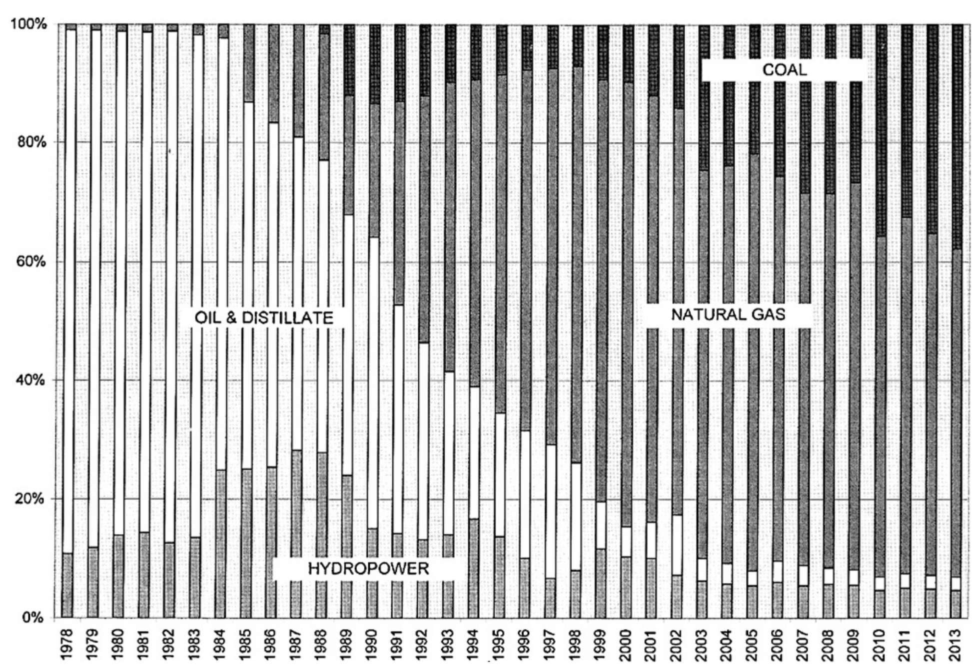


Fig. 1. Energy mix trend in power generation.

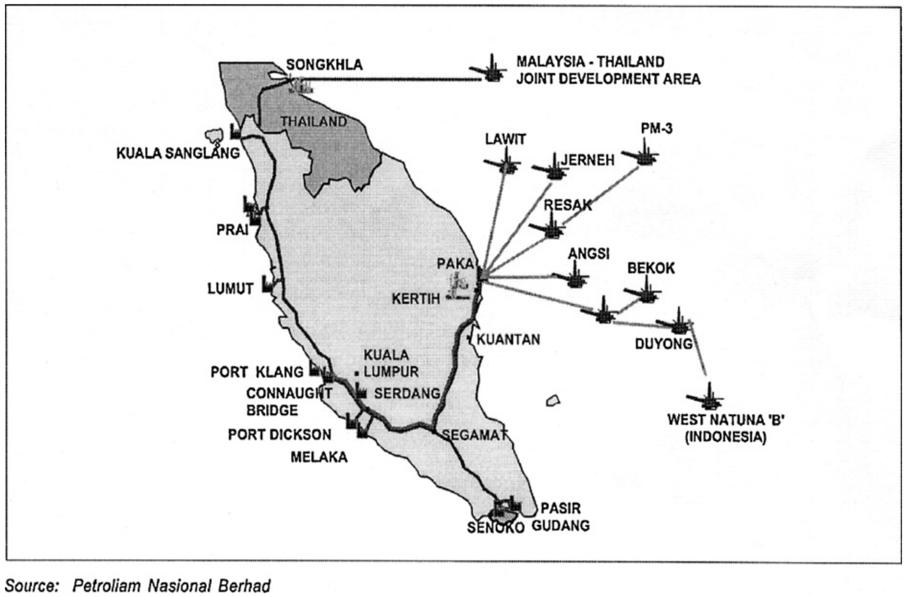


Fig. 2. Natural gas supply network [6].

2.1. Natural gas

In 2010, Malaysia was the world's tenth largest holder of natural gas reserves with proven reserves of 83 trillion cubic feet (Tcf), which 38% is found off the east coast of Peninsula Malaysia and 48% offshore Sarawak and the remaining 14% offshore Sabah. At the rate of current production of 2.1 Tcf, Malaysia gas reserves are expected to last for another 36 years [11,12]. Malaysia has one of the most extensive natural gas pipeline networks in Asia. The Peninsular Gas Utilization (PGU) project, completed in 1998, expanded the natural gas transmission infrastructure on Peninsular Malaysia. The PGU system spans more than 880 miles and has the capacity to transport 2 billion cubic feet per day (Bcf/d) of natural gas [11].

Presently, Malaysia had significant gas exploration and development in the Malaysia–Thailand Joint Development Area, located in the lower part of the Gulf of Thailand by the two governments for joint exploration. The delivery of natural gas into Malaysia started in the first quarter of 2005. Natural gas was also imported from West Natuna (Indonesia) beginning in 2002. The supply sources through regional network as shown in Fig. 2 delivered about 20% of Malaysia total gas supply in 2010. In 2009, natural gas contributes about 75% of the energy mix in Malaysia as a source of fuel [13].

Malaysia has 21 gas-fired power plants, 18 are located in Peninsula with combined generating capacity of 12,182 MW while 3 are located in East Malaysia with capacity of 440 MW [15].

2.2. Oil

As January 2010, Malaysia held proven oil reserves of 4 billion barrels which is 56% of the reserves exist in the Peninsula and while 19% exist in East Malaysia and ranked 24th in terms of world oil reserves [11,14]. The average production of domestic crude oil and condensate had increased from 681,000 barrels per day (bbl/d) in 2000 to 727,000 bbl/d in 2005. Based on this production level, the reserves are projected to last for 19 years. The share of oil in the generation mix was seen to decline from 4.2% in 2000, then 2.2% in 2005 and drastically downed to 0.2% in 2010 [6].

Petroleam Nasional Berhad (PETRONAS) as the national oil and gas company, holds exclusive rights to all oil and gas exploration and production projects in Malaysia. The country's oil production has been gradually decreasing since reaching its peak of 882,000 bbl/d in 2004 due to its maturing offshore reservoirs. Malaysia consumes the majority of its production and domestic consumption has been rising as production has been falling. Exports in 2009 were downed to 157,000 bbl/d. However, the government is focused on opening up new investment opportunities by enhancing output from existing fields and developing new fields in deepwater areas offshore Sarawak and Sabah [11]. Fig. 3 shows the oil's production and consumption trends since 1990.

Malaysia has mainly 5 oil-fired power plants; Gelugor Power Station in Penang with generation capacity of 398 MW, while in Sabah, Melawa Power Sation, Sandakan Power Corporation Plant, Stratavest Power Station and Tawau Power Plant with a total generation capacity of 180 MW [15].

2.3. Coal

The coal reserves in Malaysia estimated in 2008 was about 1712 million tons which consist of 275 million tons of proven reserve, 347 million tons as indicated and 1090 million tons as inferred reserves. Most reserves are; 69% is in Sarawak, 29% is in Sabah at 29% and remaining 2% is in Peninsula. Although Malaysia has significantly large coal reserves, most of them are found in inland areas which having inadequate infrastructure that add-up to the fuel's cost. Therefore 90% of coal supplies into the country are mainly imported from Australia, Indonesia, China and South Africa [13].

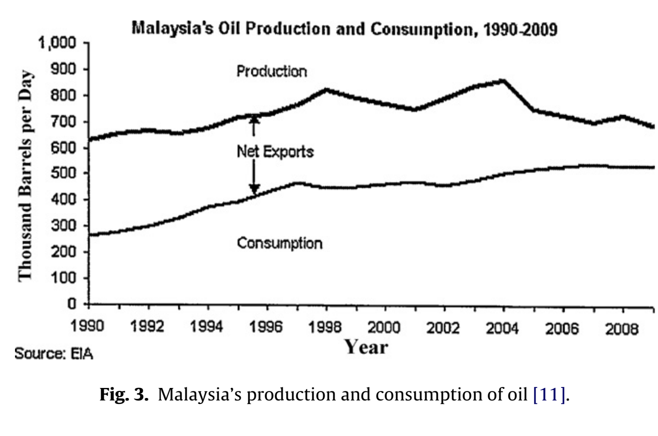


Fig. 3. Malaysia's production and consumption of oil [11].

The consumption of coal for power generation was expected to reach 19 million tons in 2010. The share of coal in the generation mix was seen to increase 8.8% in 2000, then 21.8% in 2005 and 36.5% in 2010 as Malaysia reliance on oil for electricity generation is phasing out. Efforts will be continued to enhance the security of supply by exploring the potential of developing local sources, particularly in Sarawak as well as securing long-term supplies from abroad [6]. Currently Malaysia has 6 coal-fired power stations, 4 in Peninsula with total power generation of 8215 MW and 2 in Sarawak with 220 MW of generating capacity [15].

2.4. Hydro

Malaysia's hydro power potential is assessed at 29,000 MW; 85% of potential sites are located in East Malaysia while the balance is in Peninsula. The share of hydro in the generation mix was 10% in 2000, and then declined to 5.5% in 2005 and 5.6% in 2010 as the share of coal in fuel mix ratio increases [6]. Currently there are 4 hydroelectric schemes in Peninsula with installed generating capacity of 1931 MW that involve 16 power stations located at Sungai Perak, Cameron Highlands, Terengganu and Kelantan with 21 dams in operation. While in East Malaysia, there are 4 dams; 3 in Sarawak and 1 in Sabah with installed generating capacity of 1035 MW. The Bakun Hydroelectric Project, which is still under development, has the greatest potential of adding up 2400 MW to the hydroelectric capacity when in full operation [15].

3. Issues and challenges of present fuels for power generation

The critical issue facing the fossil-fuel power generation sector in Malaysia is the over dependence on natural gas and coal as the main resources, while oil dependency has already decreasing through out the years. Malaysia is promoting coal as a fuel of choice for power generation, to free up more natural gas for export as the Malaysian government has adopted a policy of attempting to reduce the country's heavy reliance on natural gas for power generation. Sustainability and security in supplying the resources are crucial to maintain the economy and the energy needs. As for coal, 90% of the supply is imported from foreign countries as trade relations, bilateral negotiations and mutual agreements must be firmly established to ensure continuous supply of the fuel. According to the Energy Information Agency (EIA) projection, in 2010 coal price was estimated to be at USD35 per tonne and Malaysia spent nearly RM2.4 billion on imported coal in the year [32]. Depending on price escalation sensitivities such as appreciation of exchange rates, tighter demands, production cost, inflation and limited stocks, it is expected that the average delivery of coal price will escalating to nearly USD45 per tonne by year 2030. Nonetheless, coal will still remain in long-term fuel option because of its relatively low cost energy source. On the environmental issues, deployment of advance Clean Coal Technologies (CCT) to the power plants to increase the thermal efficiencies of generation and reduce the CO_2 emissions, discharge pollutants or disposal ash generally will provide greener option to the total public, even though the overall economics of new plant construction and operation is comparatively higher to a conventional plant. Eventually, the impact of increasing electricity tariff to the consumers is unavoidable thus lowering the competitiveness of the total economy if appropriate measures are not implemented.

Even though Malaysia presently has large amount of gas reserves, the depletion of supply is expected to happen by year 2046 causing future energy uncertainty. As Malaysia already reached to 75% of the energy mix for natural gas in 2009, further increasing of the fuel consumption for electrical power generation is no longer viable. Natural gas price is getting more expensive in the world's market and exporting the resource seems a better option for the economy. Projection of Malaysia gas reserves will last in next 36 years and consequently threatening the sustainability and energy security, whereby currently Malaysia is considering on alternative measures of maintaining future energy supply through new development programs and energy policies under the Ministry of Energy, Green Technology and Water (KeTTHA).

Fossil-fuel power plants undoubtedly polluting the environment, by releasing of greenhouse gases primarily recognized as carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Malaysia is committed to reduce its CO_2 emissions to 40 per cent by 2020 as compared to the CO_2 emissions in 2005 [33]. The commitment, pledged by Prime Minister Datuk Seri Najib Razak at the Conference on Climate Change in Copenhagen, Denmark in 2009 was however depended on the assistance from developed nations in realizing the climate change and global warming would directly hit Malaysia's economic survival as a developing nation.

Hydro power will still maintain as base-load and peak-load power stations as start-up and stopping are relatively easy and fast. A potential of 28,000 MW of hydro power projects could be developed in Sarawak to feed-in the Peninsula Malaysia for future energy needs. Tenaga Nasional Berhad (TNB) announced in 2009 that it will be part of a consortium to build submarine cable at a cost of RM 2 billion carrying electricity from Sarawak on Borneo to the peninsula [34]. Expectedly, harnessing further the hydro potential can generate environmental disturbance and social impact; for example the Bakun Dam construction requires the relocation of indigenous people and total ecological destruction on 69,640 ha of forest ecosystem, native animals, flora and fauna plus its unique geological features [35].

4. Future energy for power generation

Since Malaysia introduced new fuel mixed strategy from Four to Five-Fuel Diversification Strategy in 2002, renewable energy (RE) is considered as the 5th fuel for the new alternative source. The new diversification policy objectives are: (1) to encourage the utilization of renewable resources such as biomass, solar, mini hydro, etc. as additional sources of energy/electricity generation, (2) to reduce over dependence on conventional source of energy i.e. oil, gas, hydro and coal, (3) to contribute towards the preservation of the environment [16].

The Ministry of Energy, Green Technology and Water (KeTTHA) was re-established in 2009 from Ministry of Energy, Water and Communications (KTAK) by the government in the promotion of RE and efficient use of energy as energy sources. New functions and responsibilities were added to KeTTHA for planning, developing policies and programs, green technology in showing government determination to lead a new initiative addressing global issues such as environmental pollution, global warming and depletion natural resources.

Malaysia plans to achieve 985 MW or 5.5% share of renewable energy in the energy mix by 2015 as shown in Fig. 4. Currently, renewable energy contributes less than 1% to the energy mix in Malaysia. By 2020, the target is for renewable energy to comprise 11% or 2080 MW of overall electricity generation in the country and to achieve much long ambitious target to 25% of total usage of renewable energy by 2050 [17]. Fig. 5 shows the potential renewable energy sources available.

4.1. Solar

Malaysia as an equatorial country has an approximate of 4000–5000 Wh/m^2 of daily average solar radiation and a yearly

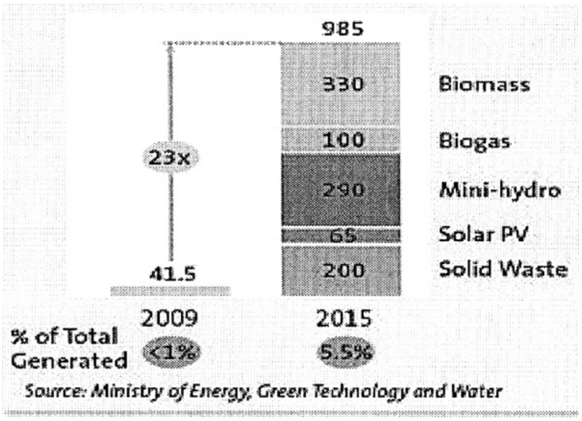


Fig. 4. Planned increase in renewable energy capacity (MW).

average of 1643 kWh/m^2 of the energy [18]. Considering that Malaysia gets on an average 4–8 h of free and bountiful sunshine everyday, the potential for solar power generation is very high and estimated at 4 times the world fossil fuel resources [8]. However at present, the real harnessing of this renewable energy source is way below its actual potential. At present, Solar Photovoltaic (PV) applications in Malaysia are restricted to rural electrification, street and garden lighting, and telecommunications, while solar water heaters are basically used for heating purposes in hotels, the food and beverage industry, and upper-class urban homes.

Photovoltaic (PV) technology was first introduced into Malaysia in the early 1980s, primarily in providing basic electricity to remote areas. Subsequently, PV technology was used to generate electricity for offshore oil and gas platforms. In 1998, on the initiative of the national power utility, Tenaga Nasional Berhad (TNB), Malaysia started to experiment with grid-connected PV system. This was motivated by the success of the German Rooftop and Japanese Sunshine programs. Between 1998 and 2002, six pilot grid-connected PV systems were installed with power capacity ranging from 2.8 kWp to 3.8 kWp. The first system was installed in July 1998 on the roof of a university and provided Malaysia's first practical experience of grid-connected PV. By the end of 2005, there were almost 470 kWp of grid-connected PV systems installed in Peninsular Malaysia, most notably the 362 kWp system at Technology Park Malaysia (TPM). The PV installation at TPM demonstrated Malaysian capability to handle and manage large PV installations [19].

The experience from the pilot grid-connected projects indicated that such PV applications in Malaysia are reliable and can produce 1.3 times more electricity when compared with similar installations in Germany. More significantly, the energy yields are rather stable from month to month as Malaysia enjoys tropical weather throughout the year.

In 2005, the Malaysian Building Integrated Photovoltaic Technology (MBIPV) was launched to create enabling environment that will lead to a sustainable BIPV market in the country and technology cost reduction. A PV system, either a stand-alone or a grid-connected, is classified as a BIPV system whenever the PV is aesthetically integrated into the building architecture and envelope. Most of the BIPV applications are grid-connected systems that are applied in urban areas.

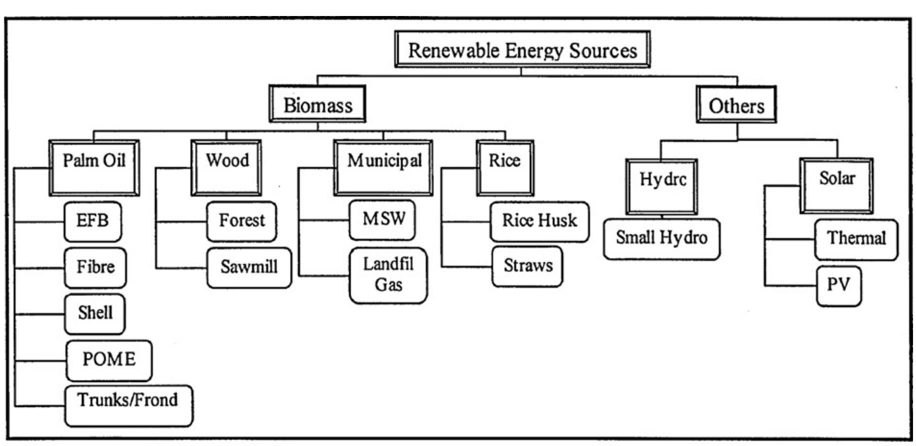
The utilization of solar energy through PV has a huge potential, offering several advantages. BIPV needs no extra land, and it generates electricity at the point of use, thus reducing electricity transmission losses. When BIPV capacity is appropriately sized, it can displace purchase of electricity, with possibility to export the surplus to the grid. Considering only the lower PV capacity value of 1 kWp for every 10 m^2 of available building roof surfaces in these sectors, the technical potential is around 11,000 MWp or 11 GWp, which could provide more than 12,000 GWh solar-generated electricity which equivalent to 20% of the national energy demand.

4.2. Biomass, biogas and municipal waste

As Malaysia is largely an agricultural based country, oil palm waste, wood waste, paddy residues (husk and straw) are considered to provide significant portion to the biomass energy. Biomass fuels contribute to 16% of the energy consumption in the country, where 51% comes from palm oil biomass waste, 27% from wood waste and 2% from paddy residues.

Residues from palm oil industry such as fruit fibers, shell empty fruit bunches, trunks and fronds are all having great potential as energy resources. This abundant supply of oil palm waste provides the strong reason for selecting biomass as the first of the renewable energy sources to be developed for large-scale application. As shown in Table 2 is the residue product ratio and potential power can be generated.

The resource is widely used in Malaysia for heat and power generation through combustion process. The excess power from this combined and heat power plant can be connected to the national grid system. Currently, the total generation capacity from oil palm residues for internal consumption is about 211 MW [18].



Source: Pusat Tenaga Malaysia (2003)

Fig. 5. Malaysian renewable energy sources [18].

Table 2
Residue product ratio and potential power from palm oil wastes.

Production ('000 ton)	Residue	Residue product ratio (%)	Residue generated ('000 ton)	Potential energy (PJ)	Potential electricity generation (MW)
59,800	EFB at 65% MC	21.14	12,641.7	57	521
	Fiber	12.72	7606.6	108	1032
	Shell	5.67	3390.7	55	545
Total solid			16,670.6	220	2098
POME (3.5 m^3/ton of CPO/65% of FFB)			38,870		320

Source: RE in ASEAN website: www.aseanenergy.org (December 2005).

Table 3
Characteristics of the biogas captured.

Fuel composition	More than 55% are methane gas
Moisture level of the biogas	Maximum at 80% moisture level
Temperature	24 °C
Calorific value	5.32 kWh/m^3
Biogas production rate	40 m^3/h
Biogas feeding system	Direct extraction from gas field
Monitored emission	NOx < 500 mg/m^3

Source: RE in ASEAN website: www.aseanenergy.org (December 2005).

Biogas is another highly potential of energy resource and commonly produced under anaerobic conditions using waste management facilities. The sources are Palm Oil Mill Effluent (POME) anaerobic ponds, industrial anaerobic ponds, other agricultural anaerobic ponds and municipal landfill gas (LFG).

The Landfill Power Generation Project Air Hitam Sanitary Landfill, Puchong, Selangor constructed in 2003 became the first grid connected RE project implemented in Malaysia using municipal waste with a total generation capacity of 2 MW. Much of the energy content of biogas is mainly dependent on the methane content [18,20]. Table 3 indicates the characteristics of the biogas captured.

With the population growth it is estimated that the amount of solid municipal solid waste (MSW) by the year 2020 is about 9 million tons per year. From that figure, the average amount of solid MSW generated per day is 24,650 tons. Thus, the potential amount of energy to be generated using the backpressure turbine system is about 500 MW. As shown in Fig. 6 is the percentage composition of municipal waste in Malaysia. As the MSW increases, MSW management is getting more crucial. Present method, the MSW is managed mainly through open landfill. However, due to rapid development and lack of new space for it, the big cities and islands are considering incineration to tackle this problem [18].

The calorific value of Malaysian MSW ranges from 1500 to 2600 kcal/kg and the energy potential from an incineration plant operating based on 1500 tons of MSW/day with an average calorific value of 2200 kcal/kg is 640 kW/day. In 2009, approximately 21,000 tons of solid waste is produced daily but only 5.5 MW of solid waste power is generated due to lack of related facilities [20].

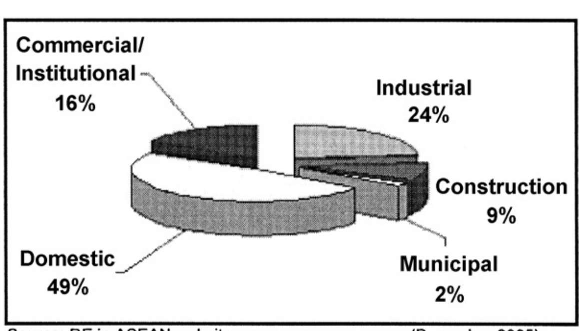


Fig. 6. Composition of municipal solid waste in Malaysia [18].

4.3. Mini-hydro

The mini-hydropower potential of the country has been assessed and viable sites have been identified. Some of these sites have been implemented with government funding under rural electrification program. These are based on run-of-the-river systems ranging from 500 kW to 1000 kW capacity. Currently, there are thirty nine units with total capacity of 16.185 MW in Peninsular Malaysia, seven units of total capacity of 2.35 MW in Sabah and five units of total capacity 5 MW in Sarawak [18]. Mini-hydro with total power of 30.4 MW was built in 2009 and potential to increased its power potential to 490 MW by 2020. Smaller scale than the mini-hydro, the micro-hydro schemes with capacity ranges from 5 kW to 100 kW are also considered as good potential for future power generation [20].

4.4. Wind

The current utilization of wind energy sources is still limited due to low average wind velocity in the whole country. The wind speed in Malaysia is light and varies from season to season in the range of 2–13 m/s. The north east monsoon which is from the month of September to March plays an important role in this region where the strongest wind comes from the South China Sea to the East Coast. University Kebangsaan Malaysia (UKM) studies in 2005 reported that the use of a 150 kW wind turbine in the Terumbu Layang-Layang and hybrid solar energy at Pulau Kapas in Terengganu demonstrate with some success. This is the first project installed in the island off the East Malaysia and on the East coast of West Malaysia.

A thorough wind research and analysis was done by Tenaga Nasional Berhad (TNB) and a group of researcher from UKM to record the average wind speed at Pulau Perhentian in Terengganu, from year 2003 to 2005 as shown in Table 4. Based from the

Table 4
Average monthly wind speed m/s recorded from 2003 to 2005.

Month	2005			2004			2003		
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
Jan	5.6	14	7.9	5.6	14	8.1	5.1	13	8.4
Feb	6.1	8.2	6.85	5.6	8.7	6.93	5.6	13.3	7.82
Mar	6.1	13.3	7.56	6.1	13.3	7.59	5.6	14.3	7.74
Apr	5.5	10.7	6.78	6.6	14.3	7.73	4.1	9.7	6.54
Mar	4.9	11.5	6.91	5.1	11.7	7.3	4.6	13.8	7.01
Jun	N.A	N.A	N.A	3.6	13.3	7.35	4.6	11.2	7.39
Jul	4.8	11.5	6.63	5.1	13.8	8.22	5.6	12.8	7.24
Aug	5	15.6	7.16	4.6	13.3	7.68	4.6	13.8	7.69
Sep	4.4	12.7	6.88	5.1	13.3	7.93	5.1	14.3	7.5
Oct	3.9	14.3	7.12	5.6	12.8	8.12	4.6	14.3	7.47
Nov	47	15.4	7.57	5.1	13.8	7.88	5.1	13.8	7.62
Dec	4.6	15.3	7.88	5.1	12.8	8.41	6.1	13.3	9.31

recorded data, 2 units of wind turbines with 100 kW total output power were installed at the suitable location together with 100 kW solar PV to perform mix operation with existing diesel generators [21].

Recently, TNB has collaborated with the Argentina's renewable energy firm, Industrias Metalurgicas Pescarmona SA (IMPSA) to determine the actual wind generation potential Malaysia has. If all goes well, the duo would form the nation's first independent power producer (IPP) running on wind-powered turbines. They have already selected the potential sites and starting to do the works for the installation of the measurement towers in collaboration with TNB.

A wind speed of at least seven meters per second (m/s) is needed to turn the blades of a wind turbine. While Malaysia only has an average wind speed of 2 m/s, there are areas that exceed the 7 m/s minimum criterion. Wind along the Malaysian-Thai border, for example, is believed to stream at nearly 15 m/s. Among the potential sites IMPSA has identified are in Kota Kinabalu, Mersing, and Kuala Terengganu. Towers of at least 80 m high would be erected to measure wind data, such as speed and consistency, in these locations. Typically, a year of 'very accurate' wind data is needed to determine the suitability of a promising site for a wind farm. According to IMPSA, it costs between US$ 1.8 million and US$ 2.5 million to generate one megawatt (MW) of wind power. The wind energy potential in Malaysia is estimated to generate between 500 and 2000 MW of power [22].

4.5. Geothermal

TNB has discovered four important geothermal power generation sites that could produce more than 2 MW of electricity in Peninsular Malaysia. As per the research study carried on jointly by two units under TNB; Generation Asset Development (GAD) and TNB Research Sdn Bhd, these projects could be fully put into use by 2016. During their first stage of feasibility study, they obtained 20% level of confidence for the projects. When entering the second phase of study, it is hope to secure a 60% confidence level by 2012 and 90% by 2013 where drilling activities would start up. TNB will utilize steam produced from hot water springs to generate electricity. The country has more than 40 thermal springs in Peninsular Malaysia as potential to generate electrical power in future [23]. In East Malaysia, at Tawau in Sabah has potential to generate electricity from geothermal sources following the discovery of a geothermal site in Apas, about 40 km from Tawau. The Mineral and Geoscience Department so far had found that there is potential to generate up to 67 MW of electricity a day to meet the energy needs of the town [24].

4.6. Ocean energy

The ocean energy can be harnessed in the form of waves, tides, ocean current, thermal difference and salinity gradient. Even though related technologies have been developed globally in the areas, but not all of these are suitable for Malaysian seas [25].

Analytical assessment has been carried out to estimate the amount of electricity to be generated by marine current turbines (MCTs) and also to evaluate the economical viability and environmental benefits of installing MCTs in Malaysia. It was identified that Pulau Jambongan, Kota Belud, and Sibu in East Malaysia are the locations with great potential for tidal energy extraction. The total amount of electricity that can be generated by MCTs on those locations is about 14.5 GWh/year. This amount is much higher than the amount of electricity of PV systems which is aimed to be generated in 2010. The government or utility company can save about RM 1.1 billions of natural gas and avoid a total greenhouse emission of 4.5 million tons per year [26].

4.7. Nuclear

Nuclear energy is dubbed as Malaysia's sixth fuel in the energy mix for power generation. As the country is predominantly based on only 3 of the 5 fuel sources i.e. natural gas, coal and hydro, Malaysia is seriously to consider on nuclear potential as future energy security as a stable base load power generation.

In December 2010, the country's energy minister, Datuk Peter Chin, announced plans to build two 1000-MW nuclear power plants by 2022. A month later, Prime Minister Datuk Seri Najib Razak announced the establishment of the Malaysian Nuclear Power Corporation, which will lead the planning process [27]. Nuclear has become a more prominent choice in balancing the energy source due to lower maintenance cost and lower tariffs in the long-run than RE. The government is looking on a balanced approach when considering RE as it would not want tariffs to go up due to higher cost and diminishing natural resources by maintaining base load power generation using fossil fuels only. Malaysia began operation of its very first nuclear reactor, a 1 MW Triga reactor for research purpose, since 1982 and has an international nuclear safeguards agreement in place since 1972 [28].

Techno-economics studies carried out for Tenaga Nasional Berhad (TNB) – Korea Electric Power Corporation (KEPCO) Nuclear Power Pre-Feasibility Study has concluded that there is a big range of costs associated with nuclear plants. According to IEA/NEA study, typically, 1 unit of 1000 MW nuclear plant's overnight cost ranges between US$ 2000/kW and US$ 4500/kW. The capital cost of a coal plant ranges between US$ 1000/kW and US$ 1500/kW. Meanwhile, a gas plant mostly ranges between US$ 400 and US$ 800/kW. Nuclear plant has the highest overnight construction costs. Nuclear plant construction costs are generally higher, compared to coal or gas-fired plants, because of higher level of technology, sophistication of equipment, quality of material & quality assurance standards.

On the other hand, operation wise, nuclear plants appear to be more favorable compared to other sources due to its lower operating costs. Once the plants are commissioned, variable or operating costs are minor. Despite the highest capital cost and Operations & Maintenance (O&M) costs among other sources, overall production cost for a nuclear plant is still the lowest. In fact, nuclear power plants have achieved the lowest production costs between coal, natural gas and oil since 2001. Production costs are the O&M and fuel costs of a power plant. Fuel costs make up 26% of the overall production costs of nuclear power plants. Fuel costs for coal, natural gas and oil, however, make up more than 80% of the production costs. Fig. 7 indicates the breakdown of production costs between various generating sources [29,30].

It can be observed the effect of doubling the fuel costs will not affect the production costs due to minor percentage of fuel cost portion. As compared to gas and coal plants, nuclear plants need refueling only once in every 15–24 months. Hence, nuclear plants are not subject to fuel price volatility like natural gas, coal and oil power plants.

In the wake of Fukushima's nuclear crisis recently, many countries such as Germany, Italy and Switzerland, where governments have opted to freeze or forgo plans to build nuclear power stations. Malaysia, which had hoped to commission its first nuclear station in 2021, will reconsider the option after reviewing the crisis at Fukushima Daiichi power plant after Japan declared a nuclear emergency when the reactors experienced partial meltdown and explosion after the 11th March 2011 earthquake and tsunami twin disasters.

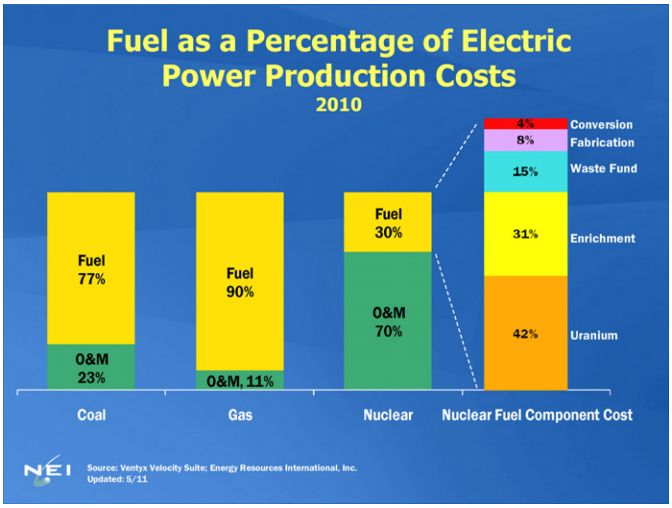


Fig. 7. Breakdown production costs between fuels for generation.

5. Energy efficiency

In considering future energy sources, it is equally important to look into the subject of energy efficiency. Increasing the energy supply is not the only answer to a stable energy future. Reducing demand through the improved efficiency of devices and procedures has the same end result.

The 9th Malaysia Plan (2006–2010) has outlined strategies for promoting energy efficiency improvement. Greater emphasis will be placed on energy efficiency under the 10th Malaysia Plan (2011–2015). To enhance Malaysia's energy efficiency, the Efficient Management of Electrical Energy Regulations 2008 was gazette on 15 December 2008. The regulations required users with a total electricity consumption of 3 million kWh or more over six consecutive months to appoint electrical energy managers and to implement efficient electrical energy management. To drive well-managed strategy and programs for energy efficiency development, the government is formulating an action plan for improving energy efficiency. The action plan will put in place a strategic direction for energy-efficiency development in the economy. The strategies under the plan will be focused on the industrial, commercial and residential sectors [2].

The objectives of energy efficient plan are; to reduce the impacts of the energy sector on the environment, improve competitiveness of products and services in the global market, conservation of fossil fuels and reduce requirements of setting up infrastructure facilities. During the plan, it is estimated the savings of 1400 GWh worth RM 238 million over the lifetime of the implemented measures and the average cost of the energy saved will be RM 0.11/kWh [31].

6. Issues and challenges of renewable energy (RE) for power generation

Possible barriers that could retard the growth of RE implementation are financial, technical, regulatory/institutional and information/educational barriers which should be addressed for feasible development in Malaysia [36]. Considering that most of RE technology and products are still new, the market prices of the RE systems will exceptionally high to compensate the cost of R&D and grants that were given on the researches. RE projects generally facing difficulties to get financial assistance from banks and creditors as payback period of the projects may exceed their expectations and limited of technological reference to secure the loan. Some RE projects require huge initial investments, practically unattractive to potential investors where the option of cheaper conventional energy resources is still available.

Technological hurdles such as different climate conditions and trend of supply sources may require unique equipment and system set-up to the country in comparing to the others. This implies the proven RE project in one country might not be suitable to another country as an example of solar, biomass, wind and ocean between countries in the tropical and temperate regions. Lacking of local expertise in efficient handling equipment and system is also a barrier to ensure stability on the RE supply. Training and educating the personnel whereby, adding to more cost and longer time constraint to realize on the project.

As for the regulatory and institutional barriers, serious and strenuous efforts toward development and expansion plans of RE to give higher priority into the country's fuel mix strategy. Special incentives, tax reductions or relieves and higher selling tariffs for RE power generations should be given by the related regulatory bodies to promote the growth of RE sector. Subsidized conventional fuel sources for existing power plants also may need to gradually reduce to reallocate the subsidy in expanding the usage of renewable energy. In addition, encouraging networking and collaboration between government agencies and private institutions in the RE areas can mutually benefit in exploring the technical and commercial viability of an RE project.

Public awareness and information on the environment and future energy crisis should also be disseminated to fully understand the direction of Malaysia future's energy scenario. Without proper knowledge, introducing to new RE technology will create unexpected outcomes and outcries from the total public as the new technology is below the level of their expectations. New introduction to RE such as wind farms, solar farms and mini-hydro units can be damaging to the natural beauty of the landscape and water streams of the areas, eventually unattractive for tourists to visit and affecting the economy of local people.

7. Conclusion

A review on existing and future energy sources for electrical power generation has been presented in detail. Malaysia will become a net energy importer by 2020 and is therefore committed to find alternative sources for its power generation. Coal and natural gas will still stay as Malaysia dominant fossil fuels in the five-fuel mix strategy into the future, where natural gas seems to be taken over by coal by the next 36 years due of its exhaustion. Over the past 10 years, other alternative sources are under serious considerations which are more dependent toward sustainable and greener options. Malaysia is in the midst of implementing a number of initiatives with regard to policy review, research and development (R&D) and applications in this area. Emphasis had been given to the development of renewable energy focusing on harnessing energy from resources such as solar, biomass, mini-hydro, wind and tidal energy. Necessary steps in developing the technology roadmap in the areas had been implemented where the use of RE plays an ever increasing role in meeting the requirements of Malaysia's energy security and the effects of climate change due to the greenhouse gases emission.

References

[1] Kaundinya DP, Balachandra P, Ravindranath NH. Grid-connected versus stand-alone energy systems for decentralized power – a review of literature. Renewable and Sustainable Energy Reviews 2009;13(8):2041–50.
[2] APEC Energy Overview 2009. http://www.ieej.or.jp/aperc/2009pdf/Overview2009.pdf [retrieved 11.05.11].
[3] Table 1 Population Size and Age Structure. http://www.unescap.org/esid/psis/population/5appc/doc/Malaysia_country_report.doc [retrieved 10.05.11].

[4] http://www.indexmundi.com/malaysia/economy_profile.html [retrieved 10.05.11].
[5] APEC Energy Demand and Supply Outlook 2006. http://www.ieej.or.jp/aperc/2006pdf/Outlook2006/ER_Malaysia.pdf [retrieved 05.05.2011].
[6] Chapter 19: Sustainable Energy Development. Ninth Malaysia Plan 2006–2010. p. 399.
[7] http://www.kettha.gov.my/en/content/national-energy-policy [retrieved 11.05.11].
[8] Oh TH, Pang SY, Chua SC. Energy policy and alternative energy in Malaysia: issues and challenges for sustainable growth. Renewable and Sustainable Energy Reviews 2010;14(x):1241–52.
[9] A Brief Presentation on the Electricity Malaysia Supply Industry. http://www.iea.org/work/2008/bangkok/malaysia.pdf [retrieved 17.05.11].
[10] The Global Economic Crisis slows power generation in Malaysia. http://www.articlesbase.com/strategic-planning-articles/the-global-economic-crisis-slows-power-generation-in-malaysia-4232293.html [retrieved 17.05.11].
[11] Malaysia Energy Data, Statistics and Analysis – Oil, Gas, Electricity, Coal http://www.eia.doe.gov/emeu/cabs/Malaysia/pdf.pdf [retrieved 24.05.11].
[12] Malaysian Natural Gas Reserves. http://www.gasmalaysia.com/about_gas/malaysian_ng_reserves.htm [retrieved 24.05.11].
[13] Energy Mix and Alternatives Energy for Sustainable Development in Malaysia. Alia Farhana Binti JAMALUDIN,UPM. http://www.nodai.ac.jp/cip/iss/english/9th_iss/fullpaper/2-2-4upm-jamaludin.pdf.
[14] http://en.wikipedia.org/wiki/Economy_of_Malaysia [retrieved 26.05.11].
[15] http://en.wikipedia.org/wiki/List_of_power_stations_in_Malaysia [retrieved 26.05.11].
[16] Energy sector embracing climate change by Pusat Tenaga Malaysia. In: National conference on climate change preparedness towards policy changes. 2007. http://www.undp.org.my/uploads/a_Energy_sector_PTM.pdf [retrieved 30.05.11].
[17] http://envdevmalaysia.wordpress.com/2011/03/26/renewable-energy-needs-a-push/ [retrieved 30.05.11].
[18] Overview of Policy Instruments for the Promotion of Renewable Energy and Energy Efficiency in Malaysia Background Report. http://www.serd.ait.ac.th/cogen/62/reports/countries/malaysia.pdf [retrieved 30.05.11].
[19] http://www.renewableenergyworld.com/rea/news/article/2007/01/equatorial-sunshine-the-malaysia-bipv-programme-51560 [retrieved 30.05.11].
[20] Salsabila Ahmad S, Ab Kadir MZA, Shafie S. Current perspective of the renewable energy development in Malaysia. Renewable and Sustainable Energy Reviews 2010;15(2):897–904.
[21] Md Darus Z, Hashim NA, Manan SNA, Rahman MAA, Maulud KNA, Karim OA. The development of hybrid integrated renewable energy system (wind and solar) for sustainable living at Perhentian Island, Malaysia. European Journal of Social Sciences 2009;9(4).
[22] Malaysia – Where wind energy power is already churning. http://www.windfair.net/press/7870.html [retrieved 02.06.11].
[23] MALAYSIA. Four potential geothermal power generation sites identified by TNB. http://www.powergenworldwide.com/index/display/wire-news-display/1413130854.html [retrieved 02.06.11].
[24] Malaysia with geothermal potential at Tawau, Sabah. http://thinkgeoenergy.com/archives/2121 [retrieved 02.06.11].
[25] Yaakob O, Ab Rashid T, Ariff TM, Mukti A, Afifi M. Prospects for ocean energy in Malaysia. In: International conference on energy and environment 2006 (ICEE 2006). 2006.
[26] Analytical Assessments on the Potential of Harnessing Tidal Currents For Electricity Generation in Malaysia, Lim Yun Seng, Koh Siong Lee. http://www.utar.edu.my/contentRandD.jsp?catid=9&contentid=417&2nd contentid=1298 [retrieved 03.06.11].
[27] http://www.thebulletin.org/web-edition/op-eds/the-sixth-fuel-nuclear-energy-malaysia [retrieved 03.06.11].
[28] http://www.theborneopost.com/2010/12/20/malaysia-goes-nuclear/ [retrieved 03.06.11].
[29] MALAYSIA. Tenaga Nasional Bhd (TNB) on Nuclear Plants. http://simonthongwh.wordpress.com/2011/06/02/malaysia-tenaga-nasional-bhd-tnb-on-the-economics-of-nuclear-plants/ [retrieved 03.06.11].
[30] http://www.nei.org/resourcesandstats/documentlibrary/reliableandaffordableenergy/graphicsandcharts/fuelaspercentelectricproductioncosts/ [retrieved 03.06.11].
[31] Energy Efficient Programs in Malaysia. http://www.resourcesaver.com/file/toolmanager/O105UF1253.pdf [retrieved 08.06.11].
[32] Malaysia: ENERGY SECTOR – Coal Development in Malaysia http://www.egcfe.ewg.apec.org/publications/proceedings/CFE/Hanoi_2007/1-2_Ghazali.pdf [retrieved 22.02.12].
[33] http://www.carbonoffsetsdaily.com/news-channels/asia/efficient-solid-waste-management-the-answer-to-lower-carbon-emissions-39539.htm [retrieved 23.02.12].
[34] http://www.reuters.com/article/2011/04/29/tenaga-hydropower-idUSL3E7FT0G120110429 [retrieved 23.02.12].
[35] Low ST, Mohammed AH, Choong WW, Alias B. Facilities management: paths of Malaysia to achieve energy sustainability. International Journal of Facility Management 2010;1(November (2)).
[36] Mustapa SI, Peng LY, Hashim AH. Issues and challenges of renewable energy development: a Malaysian experience. In: PEA-AIT international conference on energy and sustainable development: issues and strategies (ESD 2010). 2010.